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DYNAMIC MODELING OF CENTRAL ENVIRONMENTAL DESCRIPTORS FOR EASTERN AND WESTERN EUROPE

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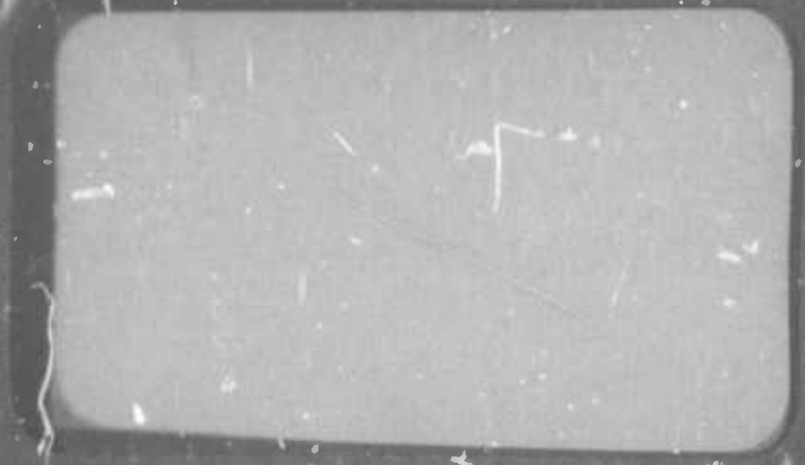

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13. ABSTRACT

This paper describes the construction of a fully interactive forecasting model. The model will be used to forecast five central environmental descriptors: national power base, internal instability, international conflict, international alignment, and economic interdependence. The model describes a system in which all five central environmental descriptors are related to one another and are forecast simultaneously.

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In order to exercise some control over our future economic, political, and physical environment, we require knowledge about the nature of that environment under specified conditions. We must identify those factors or forces that will be prominent in shaping our future and determine the impact they will have upon our future environment. It is within this context that long-range environmental forecasting assumes great importance. Yet, as the world becomes more complex and interdependent, the generation of such knowledge becomes increasingly difficult. Quite clearly, as the solutions to many of our problems have other problems hidden within them, it becomes more difficult to forecast the entire effect of given policies, practices, and patterns of behavior upon our total environment. For example, many analysts[1] failed to foresee the impact of stricter pollution control policies upon the demand for and availability of nonhuman energy sources. Others regarded industrialized agriculture as a long-term means of providing food for the world's problems without considering the effects of that kind of food-growing process upon the productivity of the land.

It is particularly important that analysts recognize these previous failures since the cost of misunderstanding accelerates as the world steadily becomes more interdependent. Such high costs point to the need for systematic approaches to long-range forecasting that are specifically designed to analyze the interdependencies of the problems we face.

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[1] See, for example, Herman Kahn and Anthony Weiner, The Year 2000 (New York: Macmillan Co., 1967).

Therefore in developing and evaluating long-range forecasting techniques, we seek techniques that help identify important linkages among problems.

Three presently-developed forecasting methods that are systematic enough to explicitly recognize and control the interdependencies among our problems are econometric forecasting, simulation forecasting, and system dynamics forecasting. Each of these techniques is especially useful for one or more phases of the long-range forecasting process. Since the remainder of the paper will consider the methodological framework of our particular forecasting effort as well as the details of the forecasting project, it is worth placing both in focus by considering the technical environment in which the forecast will be undertaken. What follows then is a brief discussion of the strengths and weaknesses of each of these methods as they bear upon the general requirements of long-range forecasting.

A. ECONOMETRIC FORECASTING

During the past few years econometricians have developed reasonably complex and realistic models of our economic environment.[2] These

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[2] See Gary Fromm and Lawrence R. Klein, "The Brookings - SSRC Quarterly Econometric Model of the United States: Model Properties," American Economic Review, Vol. 55 (1965), pp. 348-361; Gary Fromm, "An Evaluation of Monetary Policy Instruments," The Brookings Model: Some Further Results, J.S. Duesenberry, et al., eds., (Chicago: Rand McNally and Co., Inc., 1969); George Green, "Short-and Long-Term Simulations with the OBE Econometric Model," (Conference on Econometric Models of Cyclical Behavior, Harvard University, November 1969); M. Liebenberg, A.A. Popkin, and P. Popkin, "A Quarterly Econometric Model of the United States," Survey of Current Business, Vol. 46 (1966), pp. 13-39; and M.K. Evans and L.R. Klein, The Wharton Econometric Forecasting Model, (2nd ed.; Philadelphia: Wharton School, University of Pennsylvania Press, 1968).

models have been used, in turn, to produce relatively accurate short-term forecasts of that economic environment. The basic approach used by econometricians has been to isolate some set of predictors that are strongly linked to a set of variables that describe the salient aspects of the economic environment. They estimated the nature of linkages between the predictor and descriptor variables, taking into account linkages among the descriptor variables themselves, and used known values of the predictors to make short-term forecasts of the descriptors of our economic environment.

Econometric forecasting models are strictly dynamic since they consider the relationships among the descriptor variables as well as the relationships between the descriptors and their predictors. Usually, however, they have been used to forecast the values of the economic descriptors for only a single future time frame. That is, current values of the predictors are used to make forecasts about the values of the economic descriptors for the next quarter, or for the next year, or for five years hence, or for any given future time. Used alone, econometric forecasting techniques are not particularly appropriate for generating forecasts of some series of future time frames.

Moreover, econometric models rest upon a set of fixed, estimated linkages among the descriptors of interest, and between those descriptors and their predictors. While econometricians have concentrated on developing and improving methods for generating such estimates, they have not developed methods for explicitly altering those estimated linkages, either as some function of time or as some function of the predictor variables. In short, econometric forecasting provides the techniques for developing very good estimates of the linkages between descriptors of our environment and predictors of those descriptor variables, but those estimates are fixed for the duration of a given forecast. Econometric

forecasters, then, sacrifice flexibility for initially accurate estimates of the relationships among the variables they are examining.

B. SIMULATION FORECASTING

Simulation techniques have generally been divided into two classes: discrete and continuous simulation.[3] When we speak of simulation forecasting we refer specifically to discrete simulation techniques. Discrete simulation is essentially event-powered; that is, the outputs of a simulation forecast depend upon the event occurrences that are input into the model and the hypothesized effects of given events or event classes. Discrete simulation offers the analyst tremendous flexibility in the generation of a forecast; he can alter the inputs to the simulation model or the parameters of that model itself at any point in the simulation process so as to examine hypothesized occurrences or changes in the impact of occurrences.

However, simulation methods do not themselves offer guidelines or methods for developing the parameter estimates of the simulation models.[4] That is, simulation techniques allow the analyst to examine the impact of alternative estimates of the linkages among variables in his system and alternative values of those variables themselves; but they do not provide guidelines for the generation of those estimates. In

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[3] See Michael R. Leavitt, "Computer Simulation," in Forecasting in International Relations: Theory, Methods, Problems, Prospects, ed. by Nazli Choucri and Thomas W. Robinson (San Francisco: W. H. Freeman and Company, forthcoming).

[4] See Thomas H. Naylor, ed., The Design of Computer Simulation Experiments (Durham, N. C.: Duke University Press, 1969), for a survey of the techniques to develop such estimates.

short, the simulation modeler must turn to other methods for the generation of the parameter values in his model; all too often simulators have essentially "guesstimated" those values.[5] The output of a simulation model may be highly dependent upon the parameter values of the model, and simulation techniques do not offer the analyst guidelines for evaluating the quality of the estimates of those parameters.

C. SYSTEM DYNAMICS FORECASTING

We view system dynamics forecasting as a special case of continuous simulation. System dynamics refers to a forecasting technique developed and first utilized by Jay W. Forrester.[6] Forrester attempted to determine the relationships among a set of environmental descriptors and to determine simultaneously the effects upon all of them from changes

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[5] This was done for non-forecasting purposes in two models of international alliances: Michael R. Leavitt, "A Computer Simulation of International Alliance Behavior" (unpublished Ph.D. dissertation, Department of Political Science, Northwestern University, Evanston, Illinois, 1971 and Dina Zinnes, Douglas Van Houweling, and Richard Van Atta, 'A Test of the Balance of Power Theory in a Computer Simulation" (Evanston, Ill.: Northwestern University, 1969).

[6] See Jay W. Forrester, Industrial Dynamics (Cambridge: The M.I.T. Press, 1961); Jay W. Forrester, Urban Dynamics (Cambridge: The M.I.T. Press, 1969); Jay W. Forrester, World Dynamics (Cambridge: Wright-Allen Press, Inc., 1971); Dennis L. Meadows and Donella H. Meadows, eds., Toward Global Equilibrium: Collected Papers (Cambridge: Wright-Allen Press, Inc., 1973); and Donella H. Meadows, Dennis L. Meadows, Jorgen Randers, and William W. Behrens, III, The Limits to Growth (New York: Universe Books, 1972). See also W. Ross Ashby, Design for a Brain (London: Chapman & Hall, Ltd., 1952); W. Ross Ashby, An Introduction to Cybernetics (New York: John Wiley & Sons, Inc., 1963); and W. Ross Ashby, "Regulation and Control," in Modern Systems Research for the Behavioral Scientist, ed. by Walter Buckley (Chicago: Aldine Publishing Company, 1968), pp. 296-303.

in any one or any subset of those descriptors. System dynamics provides the same flexibility as discrete simulation; it permits the analyst to alter assumptions, or estimates, at any point during the forecasting process to determine the impact of those alterations. The essential difference between the two is that system dynamics is rate-driven; it examines the effects of various rates of change in the descriptors of interest, while discrete simulation is driven by occurrences of events. Of course, if the impact of events can be interpreted in terms of rate changes, the two become identical.

System dynamics also suffers from the lack of criteria for evaluating the estimates of linkages among the variables of interest. The analyst is offered no systematic means for selecting among alternative estimates of the parameters of his model, which, in the system dynamics approach, take the form of rates. That is, the method does not contain specific and replicable guidelines for generating the very parameters that act as its "driving force." In its applications, moreover, system dynamics models have relied upon "best guesses" for the values of their parameters.[7]

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[7] See Forrester's discussion in World Dynamics, pp. 17-18 and p. 32.

II. THE REQUIREMENTS OF LONG-RANGE FORECASTING

As the above discussion suggests, the evaluation of a long-range forecasting effort rests upon two criteria. First, the assumptions of any long-range forecasting model must be consistent with observed reality, with intersubjective perceptions of the nature of our world. Second, those assumptions must admit systematic examination; that is, we must be able to examine them in the context of an experimental setting. To appreciate the importance and the implications of these two criteria, we will discuss them in somewhat greater detail.

A. QUALITY OF ASSUMPTIONS

Any qualitative or quantitative forecast, either of the short- or the long-range variety, rests fundamentally upon the assumptions of the forecasting model utilized. The forecasts themselves can only be valid to the extent that the assumptions of the forecasting model are accurate reflections of the nature of processes in the real world. There are two steps in the abstraction of real world processes in a modeling effort. The first step concerns whether we, as observers of social reality, perceive that reality as it, in fact, exists. Phenomenological arguments notwithstanding, there is no way to be sure that our perceptions of reality are consistent with its "true" nature; the perceiver always imposes his own order, his own "reality," upon the world he sees. Nonetheless, philosophers of science have long recognized that some assurance of the coincidence of our perceptions and reality can be given, and that such assurance depends upon the intersubjectivity of observations. Simply put, this means that when nearly everyone sees the same thing, we can assume that it exists. This criteria, in short, implies

that assumptions about the real world must be generated in a systematic and replicable manner; "guesstimates" clearly are inconsistent with these requirements.

B. EVALUATION OF ASSUMPTIONS

Even when assumptions have been so generated, however, they must still be evaluated with respect to their implications. Despite the fact that nearly everyone in Columbus' day believed that the world was flat, the quality of that belief could not be evaluated until its implications were tested, that is, until someone either sailed around the world or fell off the edge. Consistent with the thrust of scientific philosophy, we regard the experimental setting as the most powerful and convincing means of evaluating the implications of a given assumption or set of assumptions.

When we speak of the experimental setting, however, we do not refer to the existence of a laboratory, gauges, measuring instruments or what have you, although these may be important in particular experimental settings. Rather, we refer to the manner in which the implications of assumptions are tested. Specifically, we see the experimental setting as composed of two elements:

1) The generation of variations in the assumptions under examination, variations sufficient to produce observable differences in outcomes. Obviously, sailing half way around the world would not test the belief that the world was flat, for one could have stopped but a single mile from the edge.

2) The existence of controls for other possible influences on the outcomes generated. Using the same example, one could have, without proper navigational care, sailed in a circle around the edge of a flat world, arrived at his starting point, and incorrectly inferred that the world was, in fact, round.

In short, evaluation of the quality of assumptions requires (a) manipulating the situation so as to bring into play various possible assumptions, and (b) holding all other things equal, examining the effects of those manipulations upon the variables of interest. By using experimental methodologies that contain these two characteristics, we can make the most powerful tests of the quality of our assumptions about the world and the most conclusive tests of the validity of our forecasting models.

C. SELECTION OF A FORECASTING TECHNIQUE

What we seek to develop then is a long-range forecasting technique that both allows the generation of "truthful" assumptions about our environment and permits ready evaluation of the quality of those assumptions. To do this we will combine econometric forecasting techniques and simulation forecasting techniques. As we noted earlier, econometricians have developed methods that permit high-quality estimation of the parameters of a forecasting model. These parameters are the mathematical representations of the substantive assumptions in the model. Simulation forecasting, in turn, is an ideal setting for conducting experiments about the implications of those generated assumptions or estimated parameters.[8]

Although the model we seek to develop is, strictly speaking, a continuous model, we can treat it with a discrete simulation technique. This allows the examination of the results of various events given the assumptions of

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[8] For additional discussion of simulation techniques as an experimental form, see Leavitt, "Computer Simulation." See also Thomas H. Naylor, ed., The Design of Computer Simulation Experiments, and Thomas H. Naylor, ed., Computer Simulation Experiments with Models of Economic Systems (New York: John Wiley & Sons, Inc., 1971).

the model, that is, the examination of the implications of those assumptions in the context of a wide variety of situations. The ability to manipulate assumptions (holding all other things equal) permits the control necessary to utilize powerful experimental techniques.

These, then, are the methodological considerations that lead us to combine the econometric forecasting technique with simulation forecasting. The following sections describe the particular substantive setting in which we develop and evaluate the usefulness of this forecasting model and the particular methods employed in this study.

III. A GENERAL SYSTEMS FRAMEWORK FOR FORECASTING

Our substantive research paradigm is developed out of the general systems framework.[9] Consistent with that body of literature, the economic and political environment of an area can be usefully described by some set of variables that are both of theoretical importance and of interest to users in the policymaking community. This set of variables has had numerous names in the general systems literature: "world problematique" and "essential variables," among others. We use the term central environmental descriptors to identify that set of variables that describe an area's economic and political environment. We have analyzed and forecast five central environmental descriptors: national power base, internal instability, economic interdependence, international alignment, and international conflict.

Of course, no small set of descriptors can adequately describe every aspect of an environment. Any such effort must rely upon the creation of some model of that environment, some manageable abstraction of the thousands of potentially important aspects of that environment. A model in this sense, then, is an ordering schema that designates some subset of variables as "relevant" and examines that subset to determine whether all the important aspects of the environment under examination have been adequately described and forecast. Our efforts require the selection of some small part of the environment of interest for examination, a selection based upon the orientations of the researchers and the needs of the user community. Any such selection can be criticized by other

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[9] See Ashby, Design for a Brain, for a most useful discussion and application of this framework.

researchers or other users for failing to be consistent with their theoretical orientations or their needs. Although our selections are not the only possible means of abstracting and ordering the economic and political environment of Europe, they are particularly useful for developing a long-range forecasting technology that will satisfy the needs of users in the national security community.

We seek to isolate a set of factors or predictors that are strongly related to the central environmental descriptors of interest and for which future values can be generated. Once the relationships are found, these future values will be used to forecast the central environmental descriptors. This goal requires, in itself, identifying relationships between exogenous predictors and the descriptors, and does not necessarily involve interrelationships among those descriptors themselves. We will expand the long-range forecasting technique to include consideration of those interrelationships in order to reduce the restrictiveness of assumptions about the relationships involving those descriptors. We can thereby increase the precision of the long-range forecasts generated. In short, we seek to build a fully interactive model that includes all descriptors of interest, and to link them as an integrated set with the most useful forecasting predictors.

Let us emphasize again that many previous long-range forecasting efforts either identified relationships between environmental descriptors and exogenous predictors or identified relationships among those descriptors themselves. Both approaches are valuable as well as compatible. We seek an extension of the long-range forecasting technique so that all central environmental descriptors can be simultaneously estimated from some set of predictor variables. In our effort to combine these two aspects of estimation, then, we will take full advantage of the strengths of the econometric approach to forecasting in estimating linkages among

descriptors and linkages between descriptors and predictor variables.

For this purpose it is necessary to develop a model that explicitly specifies the relationships among those descriptors so that forecasts of one of the descriptors can aid in forecasting the others. Once that task is completed, the effects of predictor variables upon all descriptors can be deduced and the entire set of central environmental descriptors can be estimated simultaneously by using information about their interrelationships and predictor variables.

This is not our first work on simultaneously-interacting systems. Previously, we examined some of the law enforcement mechanisms in this country in an attempt to model their interaction with the environments within which they operate.[10] Specifically, we suggested that with regard to the creation of crime rates, the environment of political systems provides a primary driving positive-feedback loop, while agencies of those systems provide an attenuating negative-feedback loop. This research was an attempt to model systems behavior with respect to the theoretical work of Ashby.[11] Ashby suggested that systems operate in environments that place differential pressures upon the system at different times, pressures that are reflected in the values of some "essential variables," or descriptors of the state of the system. He then suggested that systems attenuate the effects of these pressures by adjusting various mechanisms by which they interface with their environments. In applying Ashby's

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[10] Herman M. Weil, "Urbanization and Public Order: First Steps Toward An Adaptive Theory" (unpublished Ph.D. dissertation, Northwestern University, 1973); and Herman M. Weil, "Environmental and Bureaucratic Generation of Crime: A Causal Analysis" (Arlington, Va.: C.A.C.I., July 1973).

[11] Ashby, Design for a Brain: An Introduction to Cybernetics, and "Regulation and Control."

model directly to complex political and social systems, however, we failed to consider that those systems' environments, as well as their internal mechanisms for interacting with the environments, contain amplifying as well as attenuating feedback processes. Because our research was not designed to disentangle these multiple feedback loops, it did not enable clear disverification of the model proposed by Ashby.

We intend to improve this general dynamic systems' model in two ways. First, we will recognize that relationships within systems, and between systems and their environments contain both amplifying and attenuating feedbacks with respect to some set of "essential variables," or central environmental descriptors. In addition, we will recognize that sets of these variables are, themselves, interrelated in complex ways. That is, a given descriptor is sensitive to the relationship between a system (its structural mechanisms) and its environment, and is also sensitive to the relationships among other descriptors, the system, and the system's environment. In short, we hope to increase our understanding of the behavior of complex political and social systems by increasing the range of complexity that we examine.

Summary

In this research, five central environmental descriptors are examined simultaneously. Each of these five descriptors is forecast as a function of the others so that the forecasts reflect the complexity of such systems. The five descriptors to be forecast include a nation's power base, its level of internal instability, the extent of its economic interdependence with other nations, its patterns of alignment with other nations, and its patterns of conflict with other nations. What follows is a brief definition of each of these descriptors and how they are measured.

IV. THE CENTRAL ENVIRONMENTAL DESCRIPTORS DEFINED

A. NATIONAL POWER BASE

A nation's power base is viewed as the material and human resources that can be brought to bear in order to effect some internal or international outcome. We do not intend here to measure a nation's power in terms of its ability to effect given outcomes. Rather, we will measure and forecast the resources it has available for those purposes.

Specifically, we intend to measure and forecast only the physical resources[12] at a nation's disposal. Intangible resources such as organizational skills, leadership qualitites, etc., which allow a nation to use those physical resources to influence outcomes are implied in the relationships between a nation's power base and other descriptors of interest. That is, these intangibles are expected to be present when a nation with a large power base can, in fact, cause some outcome to occur. In this way, we remain within the realm of the directly measurable components of a nation's power base.

More specifically, a nation's power base has two primary components: its military resources and its economic resources, each of which is subdivided into elements that reflect the nation's usable store of resources, or tools, to effect international and domestic outcomes. We are not suggesting that these components are unrelated. Rather, we feel it may be useful for forecasting to make such analytical distinctions, and then to

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[12] R. J. Rummel, The Dimensions of Nations (Beverly Hills: Sage Publications, Inc., 1972).

suggest explicitly the ways in which those two dimensions are related.

The military resource dimension of a nation's power base will be measured by the number of military personnel it has in service and the nation's expenditures for military activities, including research and development. Each of these components will be forecast to provide a composite of military power base. The economic dimension of power base will be measured by a nation's productive level, its population, and its level of energy consumption. Again, a composite of these elements of economic power base will be developed.[13]

As noted above, we feel that these two dimensions are closely related since a strong economic base is necessary to produce a strong military resource base, and that the military resource base, in turn, influences the extent to which the growth of the economy can be sustained. Hence, we seek to provide a simultaneous forecast of both components of a nation's power base so that the interactions between them will be explicitly considered in the forecasting of each.

B. INTERNAL INSTABILITY

Internal instability is viewed here as disruptive activities, or actions, that are directed against a nation's government. Anti-governmental, disruptive sentiments can certainly be non overt, that is, they can exist in a nation and result in unobservable disruption (e.g., lack of economic productivity or slackness in military training). Our focus, however, is upon observable actions in order to permit empirical forecasting of

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[13] Aaron Greenberg and Michael R. Leavitt, "National Power Base as a Component of a Long-Range Forecasting Model" (Arlington, Va.: C.A.C.I., August 1973).

instability. Further, it might be assumed that in most countries unobservable instability is usually accompanied by observable destabilizing actions. In limiting our focus to overt activities, we can rely upon reasonably accurate enumerations of the number and scope of such actions; hence we can work comfortably within the integrated long-range forecasting model.

We divide such observable anti-governmental activities into two categories: protest, which we define as those activities designed to alter governmental policies or practices; and revolution, which we consider as those actions intended to replace the governmental policymakers or change the structure of policymaking itself. We do not intend to imply by this distinction that we can impute motives to actors whose actions are known on only a third-hand[14] basis. Rather, we make these distinctions on the basis of the theoretical and empirical literature on internal instability and internal strife.[15]

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[14]The actions are known third-hand in that they are usually reported, edited, and coded (interpreted) before they are used in the forecast.

[15]See, for example, R. J. Rummel, "Dimensions of Conflict Behavior Within Nations, 1946-59," Journal of Conflict Resolution, Vol. 10 (1966), pp. 65-73; Rudolph J. Rummel, "Dimensions of Conflict Behavior Within and Between Nations," General Systems Yearbook, Vol. 8 (1963), pp. 1-50; Raymond Tanter, "Dimensions of Conflict Behavior Within and Between Nations, 1958-60," Journal of Conflict Resolution, Vol. 10 (1966), pp. 41-64; Douglas P. Bwy, "Political Instability in Latin America: The Cross-Cultural Test of a Causal Model," Latin American Research Review, Vol. 3 (1968), pp. 17-66; Ivo K. Feierabend and Rosalind L. Feierabend, "Aggressive Behaviors Within Polities, 1948-62: A Cross-National Study," Journal of Conflict Resolution, Vol. 10 (1966), pp. 249-271; Betty A. Nesvold, "Scalogram Analysis of Political Violence," Comparative Political Studies, Vol. 2 (1969), pp. 172-194; Ted Robert Gurr with Charles Ruttenberg, "The Conditions of Civil Violence: First Tests of a Causal Model," (Research Monograph No. 28, Center of International Studies, Woodrow Wilson School of Public and International Affairs, Princeton University, 1967); Ted Robert Gurr, "A Causal Model of Civil Strife: A Comparative

Two measures of protest will be utilized here: riots and anti-government demonstrations. A summary measure will be constructed by combining these two event indicators and weighting that sum by deaths resulting from domestic violence. The number of armed attacks against governmental or quasi-public institutions, weighted by deaths, is used as a measure of revolution for this analysis. Data on these events, and the associated deaths, were drawn from the New York Times Index for the years 1948-1971.[16] Although some questions can be raised concerning the comparability of this data for Eastern versus Western Europe, its general use in the empirical literature on internal instability is generally accompanied by assurances that this data source is one of the best of its type on a world-wide basis.[17]

C. ECONOMIC INTERDEPENDENCE

Consistent with the theoretical and empirical literature on economic and political integration, we believe that the degree of economic interdependence of two nations, or some set of nations, can be measured by

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Analysis Using New Indices," American Political Science Review, Vol. 62 (1968), pp. 1104-1124; Ted Robert Gurr, Why Men Rebel (Princeton: Princeton University Press, 1970); Ted Robert Gurr, "Sources of Rebellion in Western Societies: Some Quantitative Evidence," Annals of the American Academy of Political and Social Science, Vol. 391 (1970), pp. 128-144; and Ted Robert Gurr and Muriel McClelland, Political Performance: A Twelve-Nation Study (Beverly Hills: Sage Publications, Inc., 1971).

[16] For a more complete description of the data collection and indicator construction problems associated with this examination of internal instability in Europe see Herman M. Weil, "A Preliminary Analysis of Internal Instability in a Long-Range Forecasting Model (Arlington, Va.: C. A. C. I., August 1973).

[17] See Gordon Hilton with Farid Abolfathi, Robert Mahoney, and Herman Weil, "The Role of Customer Expectation in Political Science" (Northwestern University Mimeo: Spring 1972); and Farid Abolfathi, "Data Collection in the Civil Strife Project" (Northwestern University Mimeo: Spring 1972).

facets of their trade patterns.[18] That is, economic interdependence can be measured by the extent to which the economies of two nations are linked by trade. Economic interdependence, however, is an abstract concept describing the complementarity of two economies, while the quantity of trade, or linkages, between those economies is also influenced by the size of the economies, their geographical distance from one another, and other extraneous characteristics. Accordingly, the extent of trade between nations must be baselined to remove those extraneous characteristics and leave the baselined score as a representation only of their complementarity. Several techniques for constructing such scores have been developed by economists and political scientists. Each of these, however, assumes that aside from "true" economic interdependence between economies, there is some expected value of interaction, or trade, between them. Whether that expected value is based upon the relative sizes of the economies considered, the extent of worldwide or regionwide trade in which they are involved, or some other factor, the thrust of such measures is quite similar--they are measures of differences from this expected value of trade.

1. The Michaely Concentration Ratio

This measure represents the degree to which a country's trade is limited

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[18] See M. Michaely, Concentration in International Trade (Amsterdam: North Holland Publishing Co., 1962); James A. Caporaso, "Theory and Method in the Study of International Integration," International Organization, Vol. 24 (1971), pp. 228-253; Cal Clark and Susan Welch, "Western European Trade as a Measure of Integration: Untangling the Interpretations," Journal of Conflict Resolution, Vol. 16 (1972), pp. 363-382; Barry B. Hughes, "Transaction Analysis: The Impact of Operationalization," International Organization, Vol. 25 (1971), pp. 132-145; Donald J. Puchala, "International Transactions and Regional Integration," International Organization, Vol. 24 (1970), pp. 732-763; and Richard Savage and Karl Deutsch, "A Statistical Model for the Gross Analysis of Transaction Flows," Econometrics, Vol. 28 (1960), pp. 551-572.

to one or a few partners. The ratio reaches its maximum value when a nation does its trading with all but one partner, and a minimum value when its trade is dispersed equally with all other nations. The "expected value" of trade between two nations, then, is a function only of the total number of nations with which they trade. That expected value is the mean value of a nation's trade, representing complete dispersion of trading among all partners; any deviation from this is taken as a sign of interdependence among the nations with that higher value.[19]

2. The Relative Acceptance Index

This measure has qualities in common with the Michaely Concentration Ratio except that it offers greater sophistication in at least two respects. First, the Relative Acceptance (RA) Index, in gross terms, utilizes the total trade of nations as a baseline. That is, expectations about the amount of trade between a particular pair of nations under examination are generated on the basis of the total trade of each of those nations. The RA index, then, provides a measure of trade between nations that accounts for their overall activity. More importantly, however, this index differentiates a given nation's trade concentration patterns by partner nations. Thus, while the Michaely Concentration Ratio provides a score that indicates the distribution of a nation's imports or exports to all other nations, the RA index identifies a nation's major trade partners. In short, this measure provides a means for examining concentration of trade within a dyadic matrix of imports and exports.[20]

Although other measures of the distribution of international trade exist,

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[19] M. Michaely, Concentration in International Trade.

[20] Savage and Deutsch, "A Statistical Model."

they reflect essentially the same principles as those discussed here. Each measure provides some baseline, or control variables, so that the degree of interdependence in national economies can be measured above and beyond the degree of "expected" interdependence. These measures, however, can merely indicate the degree to which a nation's trade patterns are concentrated, or they can identify those areas of concentration.

Forecasting the values of any of these measures requires forecasting the volume and direction of international trade for the time period of interest. The quality of our forecasts of economic interdependence depends upon the forecasts of trade patterns used.

The method of forecasting patterns of international trade used here is best termed the income elasticity approach. Elasticity indicates how sensitive changes in one variable are to changes in another variable. The elasticity of imports (or exports) with respect to income is the percent change in imports (or exports) associated with a percentage change in national income. Thus, if the elasticity of nation A's imports from nation B with respect to nation A's income (GNP) were .5, $E_{ab} = \left(\frac{\Delta M_{ab}}{\Delta GNP_a} \right)$, a one percent increase in nation A's GNP or national income would be associated with a .5 percent increase in nation A's imports from nation B (nation B's exports to nation A).[21]

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[21] For a good discussion of income elasticities and their use in relating the levels of two or more variables see Paul Samuelson, Economics (New York: McGraw-Hill Book Company, Inc., 1961), pp. 411-431. Alternative approaches to forecasting trade can be found in Harry G. Johnson, "Factor Endowments, International Trade, and Factor Prices," The Manchester School of Economics and Social Studies (September 1957); and I. Kravis, "Availability and Other Influences on the Commodity Composition of Trade," Journal of Political Economy (April 1956).

These elasticities are often determined for different categories of a country's imports and exports. Three categories can be usefully examined: manufactured goods, agricultural goods, and raw natural materials. Industrial countries, by and large, export manufactured goods and import raw foodstuffs and raw natural materials. Manufactured goods consist primarily of capital goods and high-technology consumer goods that tend to have high income elasticities. That is, the demand for these goods increases as the incomes of the demanding nations increase. Raw agricultural goods generally have lower income elasticities inasmuch as food is an absolute necessity for the continued economic existence of a nation, and must be obtained prior to luxury goods. Raw natural materials were once thought to have rather low elasticities; but the necessity for increases in their consumption as industrialization increases, and the appearance of limited worldwide supplies of these goods is revising those estimates upward. Thus, since national income and income elasticities for imports are related, knowledge of this relationship, and good forecasts of both of these factors, can be used to provide forecasts of patterns of international trade.

Given knowledge of these conditions, economists have developed plausible forecasts of both national income (GNP) and income elasticities of imports for pairs of trading nations. The estimates of national income so developed, however, are based on economic factors only, and do not take into account the impacts of internal instability, international conflict, and international alignment patterns upon national income. Since forecasts of these other factors are to be made in this analysis, GNP can be simultaneously forecast so as to take the impact of these political factors into account. Accordingly, the estimates of national income and income elasticities of imports for dyads can be adjusted to account for the impacts of these political factors. The adjusted values are then used to compute measures of economic interdependence.

D. INTERNATIONAL ALIGNMENT

Within the context of Eastern and Western Europe, three aspects of alignment are both theoretically interesting and useful for the analysis of public policy. The first of these is the distribution of European nations' alignments with the major powers in the area (the United States and the USSR). The second concerns the extent to which European nations are aligned with the major powers. And the third involves the patterns of alignment of the European nations with one another, that is, dyadic alignments within Europe. As we suggested elsewhere,[22] examining alignment patterns with respect to the two major powers has both theoretical and practical value; yet often that approach does not differentiate nations according to types of non-alignment or multi-alignment. That is, on a single dimensional scale, one cannot determine whether a nation in the middle of the scale is unaligned with respect to either major power or is aligned to some extent with both. Such a scale also ignores the possibility that those major powers are themselves aligned. In order to consider all three of these aspects of international alignment, we use the two-dimensional schema, which amount to a modification of the bipolar alignment schema. (Traditionally, bipolar conceptualizations of alignment have been single dimensional while dyadic measures have been n-dimensional, where n = the number of nations considered in the international system.)

The letters on the following graph represent hypothetical nations, and indicate visually each nation's degree of alignment with each of the major powers. Thus, a score of (0.0, 0.0) for nation I suggests non-alignment

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[22] Herman M. Weil, "The Use of International Alignment in a Long-Range Forecasting Model" (Arlington, Va.: C.A.C.I., August 1973).

with both major powers, a score of (1.0, 1.0) for nation F suggests complete alignment with both, and a score of (1.0, 0.0) means that nation B has complete alignment with the USSR and no alignment with the United States. The scores, then, can be thought of as a set of coordinates, locating each nation in two-dimensional space. Needless to say, this model

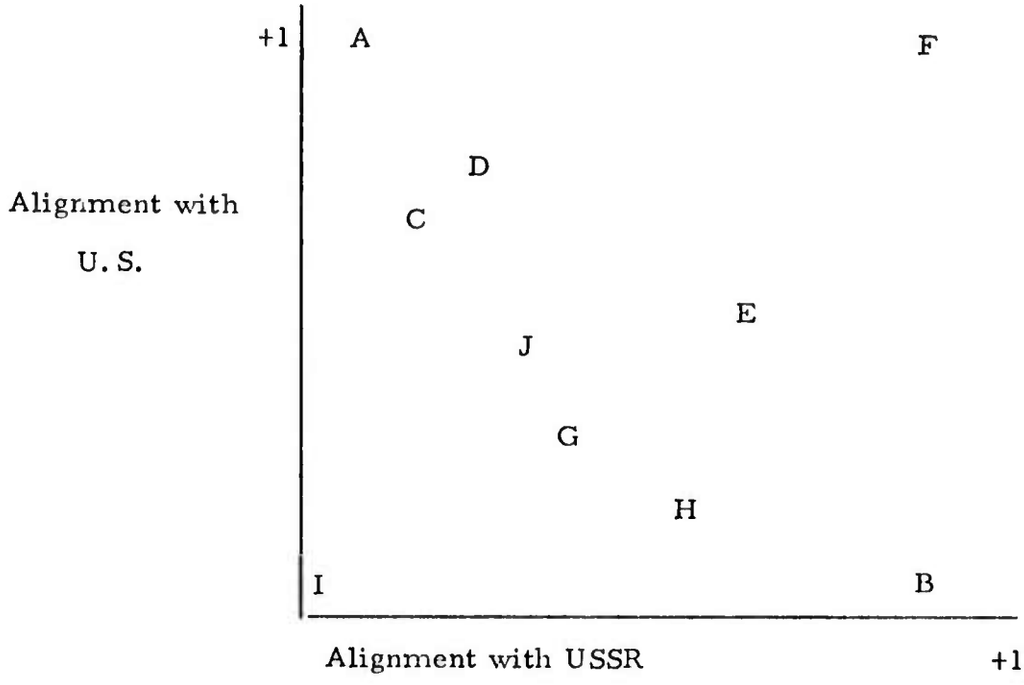

Figure 1.

can be logically extended to accommodate any number of powers with which a nation's alignment might be measured. The limitation of two dimensions is used here since alignment patterns with respect to the United States and USSR are thought to be the most theoretically interesting and practically useful. This is not to deny, of course, that alignment with respect to some other major powers (France, or even the People's Republic of China) might be considered in this manner.

The model outlined above can be transformed from the Cartesian space, where each nation is represented by a set of coordinates, to a system

where each nation is represented by a vector (a straight line) originating from the point of non-alignment (0., 0.) and ending at that nation's coordinates, as shown in Figure 2. The length of the vector (r) represents the extent to which a nation is aligned with both major powers, and the angle of that vector (O) represents the relative distribution of that alignment between the United States and the Soviet Union. Thus, a nation whose vector has an angle of 0^{o} distributes its major power alignment one hundred percent to the Soviet Union and one whose vector has an angle of 90^{o} distributes its major power alignment completely to the United States. A nation whose vector has an angle of 45^{o}, of course, is equally aligned with both major powers.

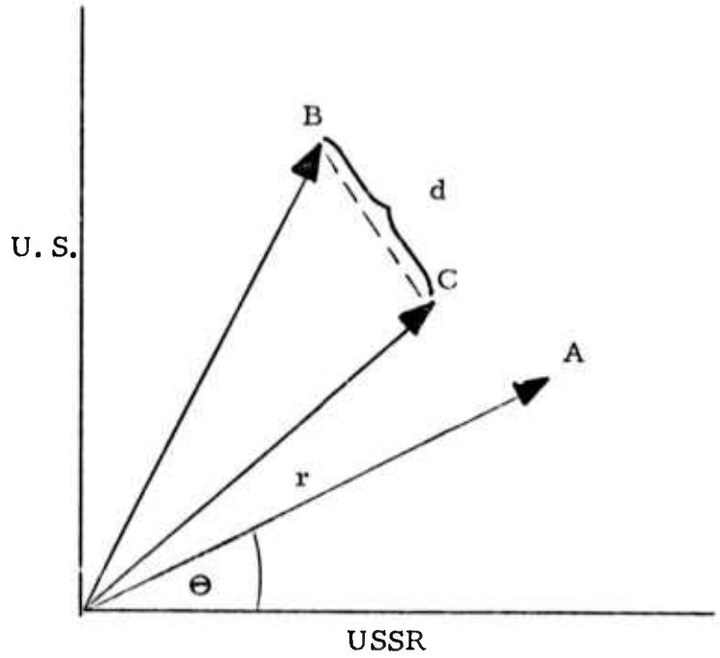

Figure 2.

Patterns of dyadic alignment, then, can be examined by computing the distance (d) between the vector endings of any two nations. Thus, nations that are far apart on this plane are less aligned than those close together. Quite obviously, nations could be far apart either because they distributed their alignment differently to the major powers, or because the relative extent of their alignment with major powers generally

is much different, that is, because the length of their respective vectors differs greatly.

This brings up the issue of how, specifically, alignment is to be defined and what measures or indicators are to be used in constructing the various scores discussed above. Leavitt identifies two basic definitions of alignment.[23] (1) The Hostility-Friendship definition considers two nations aligned if they behave in a relatively friendly or cooperative manner toward each other. This measure was used by Teune and Synnestvedt in their examination of U.S. alignments.[24] (2) The Cognitive Dissonance definition, used by Sullivan,[25] considers two nations aligned if they behave similarly toward one or more mutually salient third nation. Since the major powers identified are generally regarded as salient for all nations in Eastern and Western Europe, we can measure a nation's alignment in terms of the patterns of its behavior with regard to these two major powers. Specifically, there are two measures that can be used to determine the relative positions of nations on Figure 1 described above: 1) the U.N. voting record of a nation as compared with the votes of the U.S. and the USSR; and 2) the degree to which nations are formally aligned

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[23] Michael R. Leavitt, "A Framework for Examining the Causes of International Alliance" (Madison, Wisconsin: University of Wisconsin, July 1972). (Mimeographed.)

[24] Henry Teune and Sig Synnestvedt, "Measuring International Alignments," (Philadelphia: University of Pennsylvania Foreign Policy Research Institute Monograph Series No. 5, 1965).

[25] John D. Sullivan, "The Dimensions of United States Alignments in the Third World" (paper presented at the International Studies Association meetings, Pittsburgh, Pennsylvania, April 2-4, 1970); and John D. Sullivan, "Cooperating to Conflict: Sources of Informal Alignments," in Peace, War, and Numbers, ed. by Bruce M. Russett (Beverly Hills: Sage Publications, Inc., 1972), pp. 115-138.

through treaties with the two major powers. This information is used to compute the set of coordinates by determining the percentage of the nation's votes in agreement with the votes of the U.S. and USSR, and the percentage of a nation's treaties that include the U.S. and USSR as parties. These coordinates can then be transformed to provide a score that represents the extent of a nation's alignment with major powers (r, the length of its alignment vector), the distribution of this alignment between the United States and Soviet Union (Θ, the angle of its alignment vector), and the nation's alignment patterns with other European nations (d, the distance vector between the endpoints of any two primary alignment vectors).

E. INTERNATIONAL CONFLICT

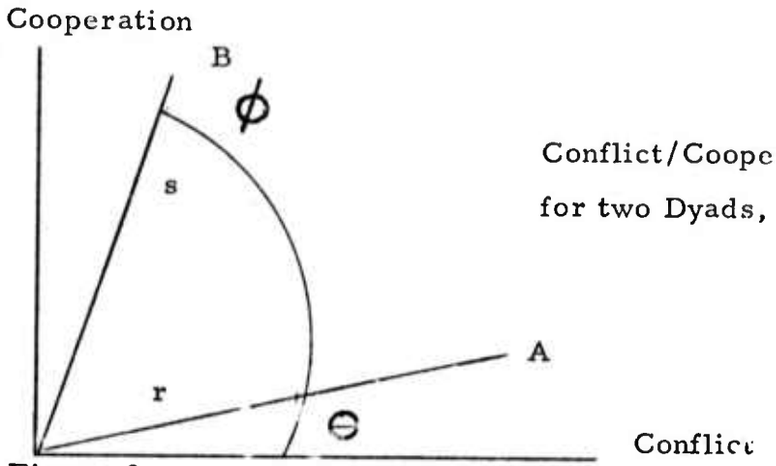
There are various ways to measure international conflict. One way relies upon a dichotomous measure, war or lack of war. By using this kind of measure, any regression analysis can generate predictions of the probability of war. Such an approach, however, does not distinguish between levels of conflict; it deals with conflict in only its most extreme form. Conflict can take many forms short of war: economic pressure, diplomatic pressure, troop mobilization, etc. This is especially true within the European context. In order to maintain constant units of analysis, we have examined Europe in the post-World War II period only. During that time only two major international military conflicts occurred, one in Hungary in 1956 and the other in Czechoslovakia in 1968. Yet conflict in its broadest sense has occurred a number of times in that time frame.

Accordingly, we have selected a definition of conflict that includes many more kinds of conflictual events, such as threats, economic sanctions, troop movements, diplomatic expulsions. A conflict score using this schema is constructed for a pair of nations for a particular time period

by assigning an intensity weight to each event category, multiplying that weight by the frequency of the category, and summing those weighted scores. Such a measure can then be treated in one of two ways. On the one hand, the number of conflict events for a pair of nations, weighted by their intensity, represents the level of conflict for those nations. Alternatively, the scores can be transformed into a measure ranging from zero to one that can be interpreted as the probability of conflict between the members of the dyad. Note, however, that this second method assumes that large numbers of conflictual acts are accompanied by high intensities of conflictual acts. To the extent that this assumption is plausible, forecasts of conflict scores can be treated as probabilities that conflict between members of a dyad will occur. If the assumption seems unrealistic, on the other hand, these scores must be treated as expected levels of conflict between those members.

Conflict, however, is only one component of a nation-pair's activities, and the context of the conflictual behavior may well affect its importance. As an illustration, consider two dyads, one of which averages 200 international interactions per year, one quarter (50) of which are conflictual, while the other dyad averages 75 events, two-thirds (also 50) of which are conflictual. The number of conflict acts is the same, and the categories of conflict may be very similar; however, the greater involvement of the first pair decreases the importance of its fifty conflictual actions as compared to the second. Thus, we will need to calculate a cooperation, or positive score to compare with the conflict, or negative score.

The two scores will be used in a manner very similar to the handling of alignment. First, the amount of conflict and cooperation can be displayed on a two-dimensional graph (Figure 3) for a particular dyad:



Conflict/Cooperation for two Dyads, A and B

Figure 3.

The total involvement of the dyads is seen as the length of the corresponding vectors (r and s), and the relative amount of conflict or cooperation is described by the angles the vectors make with the conflict axis. The smaller the angle, the more the dyad's involvement can be characterized by conflict; the larger the angle - the closer to 90^{o} - the more cooperative it is.[26] Both the total involvement and the quality of that involvement will contribute to the overall measure.

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[26] In this example, dyad A is seen as substantially more conflictual ($\cos\theta > \cos\phi$) than dyad B.

V. AN INTEGRATED FORECASTING MODEL

Having identified the five central environmental descriptors of interest in this examination, we will now suggest the possible relationships between them in the course of constructing an integrated forecasting model. Rather than present these relationships simply as a list of bivariate hypotheses, we shall discuss predictors of each descriptor and delineate the expected relationships between a descriptor and those predictors that serve as descriptors as well. Let us note at this point that this discussion does not consider exogenous predictors of any of the five central environmental descriptors, that is, those predictors that are not, themselves, subject to being forecast within the context of the model outlined.

A. PREDICTORS OF POWER BASE

As we noted earlier, a nation's power base is composed of an economic and a military dimension. The components of each dimension will be predicted independently. These components, in turn, are influenced by the values of some of the other central environmental descriptors, most notably internal instability, international conflict, and international alignment. Five components of a nation's power base have been identified. Gross national product, population, and energy consumption are included as components of the economic power base, while defense expenditures and military manpower are the components of the military power base.

A nation's gross national product is the combination of its GNP at the previous time point and the growth of that GNP for the time period

examined. That is, if we know the previous value of a nation's GNP and the rate at which that GNP is either growing or shrinking, we can effectively forecast its present gross national product. We shall treat GNP at time t-1, then, as exogenous in that it is already determined at time t. Our equation for forecasting the GNP will utilize exogenous as well as endogenous predictors. Specifically, the exogenous predictor used will be GNP as determined by an econometric analysis which is independent of the model examined here. This level will then be modified by the impact of the other descriptors in such a way that the equation forecasting the GNP is simultaneously determined with the other central environmental descriptors. Specifically,

$$GNP_t = GNP_{ex.} - \left(\frac{Instab_t}{GNP_{t-1}}\right) + \frac{(Conflict_t)\,(GNP_{t-1})}{Conflict_{t-1}} - \left(\frac{Conflict_{t-1}}{GNP_{t-1}}\right)$$

That is, the forecasted value of GNP is to be predicted from 1) the exogenously determined GNP, 2) the previous level of GNP for the nation, and 3) the level of internal instability and international conflict it faces. Presumably, countries with high levels of internal instability grow more slowly to the extent that instability adversely affects their economic production. A given level of instability will have a much larger impact on a small economy than on a larger one; that is, the degree to which that economy is disrupted by internal instability is inversely proportional to the relative size and strength of that economy prior to the occurrence of the disruption.

International conflict is also hypothesized to affect the strength of an economy in a manner relative to the size of that economy. In this case, however, international conflict is presumed to be related to the GNP in two ways. The third term of the above equation reflects the immediate effect of international conflict on national economic growth. International conflict, in its initial stages, creates demands for new goods

(mostly of a military nature). These demands are felt throughout the economy in such a way that the rate of growth of that economy is increased. This increase, of course, is proportional to the relative size of that economy since the rate of growth of the economy is altered by some constant multiplier. However, protracted international conflict appears to reduce the rate of economic growth inasmuch as such protracted conflict diverts resources from capital investment into military goods and other war-related necessities. The impact of this reduction depends upon the previous level of strength of the national economy; smaller economies are hypothesized to be more severely affected by protracted conflict than larger, more diverse economies.

Both population and energy consumption are forecast by applying exogenously-determined growth rates to present values of those variables.

$$POP_t = POP_{t-1} + DPOP(POP_{t-1}), \text{ and}$$

$$ENCON_t = ENCON_{t-1} + DENCON(ENCON_{t-1})$$

A composite measure of a nation's economic power base is computed by averaging the percentages of the total of each of these components existing in the European system that are possessed by that particular nation, and weighting this average by GNP/capita. Forecasts of the economic power base of nations, then, are computed by combining the forecasts of each of its components in the following manner:

$$ECPOW_t = \frac{\%GNP_t + \%POP_t + \%ENCON_t}{3} \times \frac{GNP_t}{POP_t}$$

Since these components, themselves, are forecast from both exogenous and endogenous predictors, economic power is viewed as a function of

GNP, population, energy consumption, internal instability, international alignment, and international conflict.

Two components of a nation's military power base, defense expenditures and military manpower, have been identified. Defense expenditures grow by some relatively constant growth factor, except as they are affected by the political central environmental descriptors and the ability of the nation's economy to support defense expenditures. Specifically, nations that are involved in new conflicts are expected to increase their defense expenditures over and above what they otherwise would spend; nations that face internal instability increase those expenditures to suppress that instability. Nations with high levels of major power alignments are expected to reduce those expenditures in accordance with the extent of those major power alignments. That is, as major powers assume some part of a nation's defense burden, that nation can reduce its own defense expenditures. That reduction is linked to the extent to which the nation is aligned with the major powers. Thus,

$$DEFEX_t = DEFEX_{t-1} + GNP_t + INSTAB_t + \frac{CONF_t}{CONF_{t-1}} - ALIGNR_t$$

Similarly, military manpower is viewed as a function of the previous level of military manpower, the population pool from which that manpower can be drawn, and the three political variables discussed above. In the same way that those variables affect defense expenditures, they will affect the level of military manpower in a nation because of the labor-intensiveness of those expenditures. Thus,

$$MILMAN_t = MILMAN_{t-1} + POP_t + INSTAB_t + \frac{CONF_t}{CONF_{t-1}} - ALIGNR_t$$

A composite index of the military power base is computed in a manner similar to that used for the economic power base. Specifically, the

average of the nation's percentage share of defense expenditures and military manpower are weighted by the qualitative factor of expenditures per man: greater firepower, better equipment, more extensive training, and hence higher levels of skill in the use of those components. Since,

$$MPOW_t = \frac{DEFEX_t + MILMAN_t}{2} \times \frac{DEFEX_t}{MILMAN_t}$$

forecasts of the military power base of nations can be easily computed from the forecasts of the components of that dimension of a nation's power base.

B. PREDICTORS OF INTERNAL INSTABILITY

Instability, in turn, depends upon several of the other endogenous descriptors. It is presumed to be directly related to previous levels of internal instability. Obviously one can see that turmoil or revolutionary activity which began in one time period and continues into the next time frame under analysis produces a strong relationship between instability in the two time frames. Probably more significant, however, is the pressure at the present time that results from arguments that justify internal instability on the basis of its past success. That is, if a nation has a history of high levels of instability that has brought changes in governmental policies and practices, or in the governmental structure itself, that history of success provides an impetus for utilizing turmoil or revolution to solve present problems or to relieve present dissatisfactions. In short, successful use of destabilizing activities reinforces the tendencies for their use.

In addition, we have hypothesized that nations that are highly dependent on the foreign sector for a large proportion of their gross national product, particularly those nations that depend upon only one

or a few foreign powers, are in a relatively precarious economic situation. This precariousness will be reflected in a lack of internal stability. That is, when the economic base of a nation can be very seriously disrupted by the activities of a single foreign power, or a few foreign powers, that nation's economy is less resilient than one that is not so dependent. To the extent that such dependence is recognized within the nation in question, it should be related to high levels of internal instability. Of course dependence, in this case, is a relative matter. A nation can depend upon the foreign sector for a large percentage of its economy, and that dependence can be concentrated among a few nations; but if its economy is initially very large and very strong, the nation's economic standing will not be severely affected by such dependence. In short, we expect the strength of a nation's economic power base to modify the relationship between high levels of interdependence with a single power and high levels of internal instability.

Instability is also related to the degree to which a nation is aligned with major powers.[27] That is, nations that are highly aligned with major powers are given added legitimacy by virtue of that alignment, and their military forces are freed, to some extent, from external defense requirements for use in suppressing internal instability. Thus, we expect nations that are more aligned with major powers to show fewer signs of internal instability than nations not so aligned. Again, however, the resources at a nation's disposal, both economic and military, modify this relationship. Nations that have the resources to deal with

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[27] See Jonathan Wilkenfeld, "Domestic and Foreign Conflict," in Conflict Behavior and Linkage Politics, ed. by Jonathan Wilkenfeld (New York: David McKay Company, Inc., 1973). See also George Liska, Nations in Alliance (Baltimore: The Johns Hopkins Press, 1962).

instability on their own do not depend upon alignment with major powers as an aid in suppressing destabilizing activities. In short, we expect nations that are more aligned with major powers to show fewer signs of instability, except when those nations have the resources to suppress that instability without the assistance of alignments with major powers.

$$INSTAB_t = INSTAB_{t-1} + \frac{(EIc)\,(EIt)_t}{ECPOW_t} - \frac{ALIGNR_t}{(ECPOW + MPOW)_t}$$

where: EIc = concentration of trade

EIt = volume of trade

C. PREDICTORS OF ECONOMIC INTERDEPENDENCE

As we noted earlier, measures of economic interdependence between nation pairs will be constructed from forecasts of international trade. Forecasts of trade between pairs of nations will be generated within the context of the integrated model by a process that was earlier termed the national income elasticity technique. That method rests upon the assumption that, because of inequities in the distribution of natural resources between nations, production cost differences, differences in tastes, and differences in importing requirements determined by the nature of production within a nation, some relationship between a nation's national income, GNP, and its imports from other nations can be found. This relationship is the elasticity of imports with regard to income.

Once this function is found, the predicted level of GNP for a nation can be used to generate forecasts of its imports from all other nations in the system. The specific equation relating imports to GNP is shown below.

$$IMPORT_t = \left(\xi \right) GNP_t$$

Obviously, since country A's imports from country B are the same as country B's exports to country A, computing the imports of all nations from all other nations gives the total trade among the nations in the system. The above equation states that imports are a function of present income, GNP. (ξ) is the elasticity coefficient of imports for income for the particular pair of nations being considered.[28]

D. PREDICTORS OF ALIGNMENT

Two scores have been developed for each nation that measure alignment with major powers. One score indicates the level of the nation's alignment with the United States and the other the level of the nation's alignment with the Soviet Union. These scores can be treated as a set of coordinates identifying the position of each nation on the plane described earlier.[29]

At the same time, those scores can be converted so that a nation's alignment patterns with the U. S. and USSR are represented by a vector, (see Figure 2) which has its origin at the point (0.0, 0.0) and its endpoint at that nation's coordinates. The length of that vector is a measure of the extent to which the nation is aligned with major powers (ALIGNR), while the angle of the vector (ALIGNΘ) apportions the nation's major power alignment between the U. S. and the Soviet Union. It is these two transformed scores, the length of the nation's alignment vector and the angle of that vector, that will be forecast here within the context of the integrated forecasting model.

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[28] Since the elasticity coefficient is computed externally to the integrated model, this equation is, within that context, an identity and contains no stochastic component, that is, no exogenous variables and no error term.

[29] The two scores can be taken together as a joint binomial distribution describing the density distribution of that plane.

The formula for the length of the alignment vector shown below indicates

$$ALIGNR_t = ALIGNR_{t-1} + \frac{INSTAB_{t-1}}{ECPOW_t + MPOW_t} + \frac{CONF_t}{CONF_{t-1}}$$

that the extent to which a nation is aligned with both major powers is a function of 1) its previous degree of alignment with major powers, 2) the extent to which it faces internal instability, and 3) the degree to which it is involved in international conflict. However, a nation's resources for dealing with internal instability without resorting to alignment determine the relationship between extent of alignment and internal instability. This qualification is based on the effects of alignments with major powers suggested above. That is, nations that are sufficiently powerful to suppress internal instability while maintaining strong external defense forces do not need alignment to quell destabilizing activities.

There is also a link between the extent to which a nation is involved in international conflict and the degree to which it is aligned with major powers. Nations that are engaged in international conflict appear to supplement their abilities to deal with that conflict by aligning themselves with major powers. We qualify this hypothesized linkage, however, by noting that nations involved in new conflicts are more likely to seek such alignments. That is, nations involved in conflicts for an extended period of time probably will not seek major power alignments because of the existence of those conflicts, but nations that become embroiled in new conflicts will do so. The third measure illustrated in the equation for extent of major power alignment, $\frac{CONF_t}{CONF_{t-1}}$, is intended to reflect this distinction.

The distribution of a nation's major power alignment between the United States and the Soviet Union is hypothesized here to be a function of 1) the previous distribution of the nation's major power alignment, 2) the extent to which it is economically interdependent with the U. S. and USSR and 3) the degree to which it is involved in conflict with the U. S. and the USSR. Specifically, a nation's distribution of major power alignment will be predicted by the previous division of a nation's major power

$$\text{ALIGNO}_t = \text{ALIGNO}_{t-1} + \left(\frac{\text{EI(US)}_t}{\text{EI(USSR)}_t} \right) + \left(\frac{\text{CONF(USSR)}_t}{\text{CONF(U. S.)}_t} \right)$$

alignment, the relative proportion of a nation's trade with the U. S. and the USSR, and the relative amount of its conflict with the USSR and the U. S. As a nation has proportionately more trade with the U. S. and proportionately more conflict with the USSR, we would expect it to distribute its major power alignment toward the U. S. Conversely, as a nation trades more with the USSR and has more conflict with the U. S., we would expect it to be more aligned with the USSR. Present values of trade and conflict are used as predictors here inasmuch as these factors are hypothesized to alter previous alignment patterns, which are themselves suggested as predictors of present allocations of major power alignment.

Let us note again that once forecasts are generated and show the extent to which the European nations show alignment with the U. S. and the USSR, transformations of the forecast values can yield coordinates that place the nations upon the alignment plane and scores that reflect the degree of alignment among those European nations themselves.

E. PREDICTORS OF INTERNATIONAL CONFLICT

The conflict score reflects the degree of conflict between given pairs of European nations; they are, then, dyadic conflict scores. International conflict is hypothesized to result from previous conflict between the members of that pair of nations, modified by the extent to which the nations with centrist governments[30] face internal instability. Specifically, such nations are expected to intensify already existing conflicts so as to direct the hostilities outward. Additionally, a modified version of the Organski hypothesis[31] is used here in two ways: conflict is suggested to be related to patterns of alignment and to differences in military power. Specifically, nations that were highly aligned at t-1 and less aligned at time t are expected to be involved in conflict with one another when the differences in their military power base are great. Thus we expect the USSR to be involved in conflict with Hungary or Czechoslovakia, but we do not expect these pressures to result in conflict between Hungary and

$$CONF(i,j)_t = CONF(i,j)_{t-1} + (INSTAB(i+j)_t \times D_1) - ((P_i + P_j)(ALIGN_{i,j_{t-1}} - ALIGN_{i,j_t}))$$

Czechoslovakia. At the same time, unaligned nations are more likely to experience conflict with one another when they have similar military

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[30] Jonathan Wilkenfeld, "Domestic and Foreign Conflict." See also R. J. Rummel, "Dimensions of Conflict Behavior Within and Between Nations," General Systems Yearbook, Vol. 8 (1963), pp. 1-50; Leo A. Hazlewood, "Externalizing Systemic Stresses: Internal Conflict as Adaptive Behavior," in Conflict Behavior and Linkage Politics, ed. by Jonathan Wilkenfeld; Tanter, "Dimensions of Conflict Behavior Within and Between Nations"; and Jonathan Wilkenfeld, "Domestic and Foreign Conflict."

[31] See A. F. K. Organski, World Politics (New York: Alfred A. Knopf, Inc., 1966).

power bases. Thus, while we would expect conflict between the U.S. and the USSR, conflict is not expected between Luxembourg and the USSR, or Yugoslavia and the U.S.

Conclusion

Let us emphasize again that we will not forecast these five central environmental descriptors--national power base, internal instability, economic interdependence, international alignment, and international conflict--solely from the hypothesized linkages between these predictors. Rather, each of these descriptors will be forecast in part from a set of exogenous, or predetermined environmental or policy-manipulable variables. What we seek in identifying the relationships, or linkages, among the descriptors themselves is to increase the accuracy, subtlety, and dynamics of the predicting model developed. The equations shown above, however, illustrate only the linkages among those descriptors themselves, and do not include the predetermined predictor variables mentioned above. Accordingly, they are not complete predictor equations for these five central environmental descriptors.

At the same time, these equations enable us to see more explicitly the kinds of linkages we have hypothesized among these descriptors. They also suggest to what extent we will have to rely upon predetermined predictors to make this integrated model identifiable, i.e., capable of being estimated. Once estimates of the parameters of this model are developed, we will be able to trace through the system the direct and indirect impacts of the predictors upon each of the five central environmental descriptors. The forecasts then generated will be integrated in that all five descriptors will be forecast simultaneously, and each forecast will take into account not only the forecast values of the predictors, but the hypothesized linkages among the descriptors themselves.

Since the project is in its early stages of formulating the precise relationships among the descriptors and variables, detailed flow charts and listings of equations are clearly premature. However, some first attempts at such relationships are presented in the following pages. The flow charts do not yet attempt to integrate the entire model, but rather illustrate the various direct and indirect effects centered around each central descriptor. There are basically three kinds of effects illustrated in the relationships.

First there are immediate, direct effects. For example, current levels of conflict affect current levels of GNP. This can be contrasted with lagged direct effects. In the same sector, for example, the previous level of conflict also has a direct effect on current GNP. In addition, there are what have been called modifying effects. In the diagram that relates the extent of major power alignment to instability, the economic and military power bases have modifying effects on the relationship itself. The greater the size of the power base, the weaker is the relationship between the extent of major power alignment and internal instability.

Each of the following diagrams uses various combinations of the three kinds of relationships. As the form of the model is modified to account for the actual (data-based) findings, the diagrams will be combined into a single picture.

Following the diagram is the collected list of the equations that will be initially estimated. There are many ways to write equations that will be consistent with the verbal descriptions and diagrammatic relationships. The form selected facilitates the estimation of the coefficients of the relationships. Once these are found, it may be preferable to convert these

equations into other forms that facilitate other phases of the forecasting process. Thus, these equations cannot be expected to remain in the same form throughout the life of the project. As first steps in the process, they are fair representations of the work envisioned.

VI. CONCLUSION

The purpose of this working paper has been to present the first stages of a model intended to produce a series of international environmental forecasts. Five central environmental descriptors - key variables that are important to any understanding of the future behavior of the international system - have been discussed, their measurements and interrelationships have been presented in some detail, and the methods of determining their future values suggested. This paper has certainly not produced hard results or forecasts, but instead has attempted to describe how the forecasts will be generated. Such an enterprise is risky in that research efforts that deal with current events frequently contain obsolete portions before they are out of production. Further, it is certain that modifications will be made, not only to the details of the model, but inevitably to certain fundamental approaches. None of this, however, negates the value of such first steps. For the model builder, the experience of formal statements of hypotheses and procedures, even where such are subject to later modification, is invaluable. For the reader, the exercise is a means of providing input to the formulation and construction of the model before work has proceeded to a stage at which modification is practically impossible. The conclusion, then, must be that the model described above is most unlikely to be implemented in its current form. The extent of the difference between the final form and the present form will be in large part a function of how successful this paper has been in presenting its basic ideas both to the readers and to its authors.

SUMMARY OF MODEL EQUATIONS

Y_1 = GNP (Gross National Product)

Y_2 = DEFEX (defense expenditures)

Y_3 = MILMAN (military manpower)

Y_4 = TURM (turmoil)

Y_5 = REVOLT (revolutionary activity)

Y_6 = ALIGNR (extent of major-power alignment)

Y_7 = ALIGNθ (distribution of major power alignment)

Y_8 = MPORT (imports of j from i)

Y_9 = CONF (conflict of i and j)

Y_{10} = POP (population)

Y_{11} = ENCON (energy consumption

Y_{12} = ECPOW (economic power base)

Y_{13} = MPOW (military power base)

X_1 = negative government sanctions

X_2 = regular power transfers

X_3 = distance from USSR

X_4 = distance from US

X_5 = dummy indicating polity type (1 = centrist, 0 = polyarchic)

X_6 = dyadic alignment (i to j)

X_7 = geographic proximity (i to j)

X_8 = dummy indicating contiguity (i to j)

X_9 = number of military treaties (history) (i to j)

X_{10} = social distance (i to j)

X_{11} = dummy indicating level of interaction (i to j)

X_{12} = Michaely Concentration Ratio

X_{13} = dummy indicating polity type (1 = personalist, 0 = others)

X_{14} = dummy indicating high alignment (1 = high alignment, 0 = other)

$$Y_1 = \beta_{10} + \beta_{11} Y_{1_{t-1}} - \gamma_{14} \frac{Y_4 + Y_5}{Y_{1_{t-1}}} + \gamma_{19} \left(\frac{Y_9 \, Y_{1_{t-1}}}{Y_{9_{t-1}}} \right) + \epsilon_1$$

$$Y_2 = \beta_{20} + \beta_{22} Y_{2_{t-1}} + \gamma_{21} Y_1 - \gamma_{26} Y_6 + \gamma_{29} \frac{Y_9}{Y_{9_{t-1}}} + \gamma_{24} (Y_4 + Y_5) + \epsilon_2$$

$$Y_3 = \beta_{30} + \beta_{33} Y_{3_{t-1}} + \beta_{310} Y_{10} - \gamma_{36} Y_6 + \gamma_{39} \frac{Y_9}{Y_{9_{t-1}}} + \gamma_{34} (Y_4 + Y_5) + \epsilon_3$$

$$Y_4 = \beta_{40} + \beta_{44} Y_{4_{t-1}} + \gamma_{48} \frac{\sum_{i=1}^{n} Y_{8_i} (X_{12})}{(Y_{12}) \, (Y_1)} - \gamma_{46} \frac{Y_6}{(Y_{12} + Y_{13})} - \gamma_{412} (Y_{12} + Y_{13}) +$$

$$\beta_{41} X_1 - \beta_{42} X_2 + \beta_{410} Y_{10} + \epsilon_4$$

$$Y_5 = \beta_{50} + \beta_{55} Y_{5_{t-1}} + \gamma_{58} \frac{\sum_{i=1}^{n} Y_{8_i} (X_{12})}{(Y_{12}) \, (Y_1)} - \gamma_{56} \frac{Y_6}{(Y_{12} + Y_{13})} - \gamma_{512} (Y_{12} + Y_{13}) +$$

$$\beta_{51} X_1 - \beta_{52} X_2 + \beta_{510} Y_{10} + \epsilon_5$$

$$Y_6 = \beta_{60} + \beta_{66} Y_{6_{t-1}} + \gamma_{64} \frac{(Y_4 + Y_5)_{t-1}}{(Y_{12} + Y_{13})} + \gamma_{69} \frac{Y_9}{Y_{9_{t-1}}} + \epsilon_6$$

$$Y_7 = \beta_{70} + \beta_{77} Y_{7_{t-1}} + \gamma_{78} \frac{Y_8(\text{USSR})}{Y_8(\text{US})} + \gamma_{79} \frac{Y_9(\text{US})}{Y_9(\text{USSR})} + \beta_{74} \frac{X_4}{X_3} + \beta_{75} X_5 + \epsilon_7$$

$$Y_8(i, j) = (\xi_{ij})(Y_1)$$

$$Y_9 = \beta_{90} + \beta_{99} Y_{9_{t-1}} + \beta_{95}([X_5(i)][Y_{4_{t-1}} + Y_{5_{t-1}}(i)] + [X_5(j)][Y_{4_{t-1}} + Y_{5_{t-1}}(j)]) +$$

$$\beta_{913}([X_{13}(i)][Y_4 + Y_5(i)] + [X_{13}(j)][Y_4 + Y_5(j)]) +$$

$$\gamma_{913}(Y_{13}(i) + Y_{13}(j)) - \beta_{914}(X_{14_{t-1}} Y_{13}(i) - Y_{13}(j)(X_{6_{t-1}} - X_{6_t})) +$$

$$\beta_{97} X_7 + \beta_{98} X_8 - \beta_{99} X_9 + \gamma_{92} \frac{Y_2(i) + Y_2(j)}{Y_1(i) + Y_1(j)} +$$

$$\beta_{910}(X_{10} X_{11}) - \gamma_{913}\left(\left|Y_{13}(i) - Y_{13}(j)\right|(-[X_{14} - 1])\right) + \epsilon_9$$

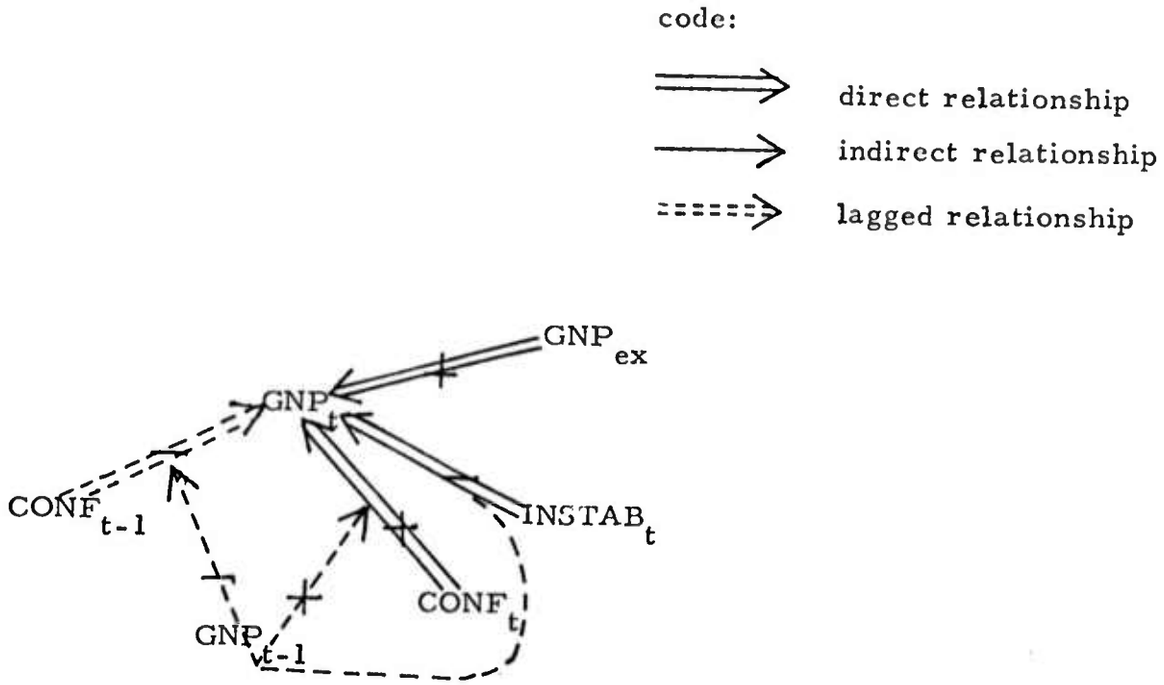
$$Y_{10} = \beta_{100} + \beta_{1010} Y_{10_{t-1}} + \epsilon_{10}$$

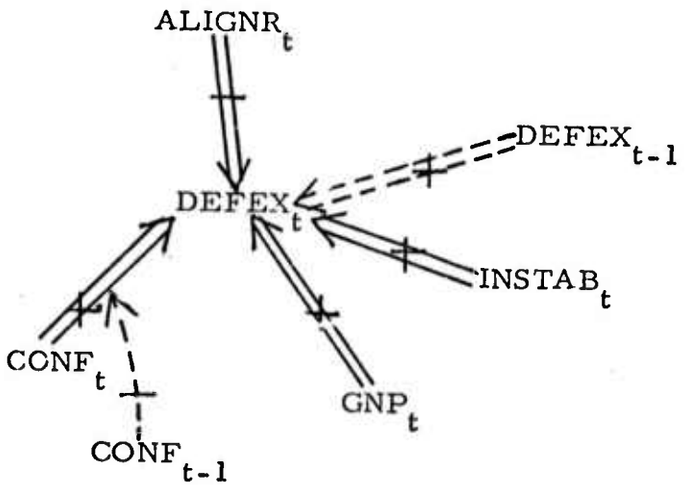
$$Y_{11} = \beta_{110} + \beta_{1111} Y_{11_{t-1}} + \epsilon_{11}$$

$$Y_{12} + (Y_1 + Y_{10} + Y_{11})(Y_1/Y_{10})$$

$$Y_{13} = (Y_2 + Y_3)(Y_2/Y_3)$$

FLOW CHARTS


code:
direct relationship
indirect relationship
lagged relationship
GNP ex
GNP t
CONF t-1
INSTAB t
CONF t
GNP t-1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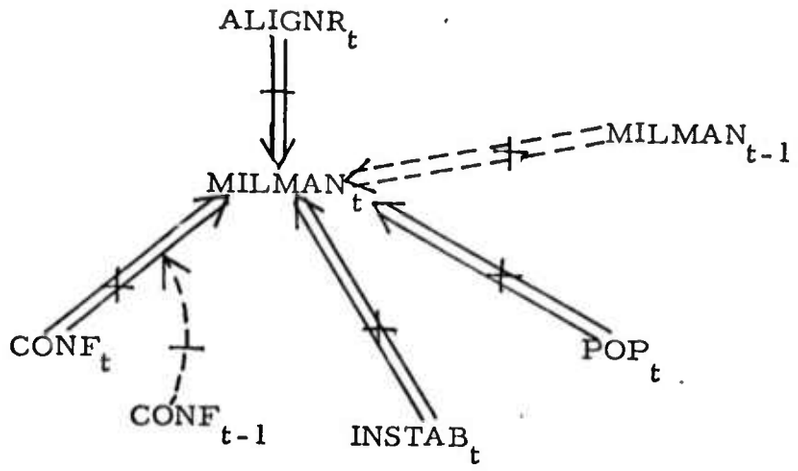
DEFEX t-1
DEFEX t
INSTAB t
CONF t
GNP t
CONF t-1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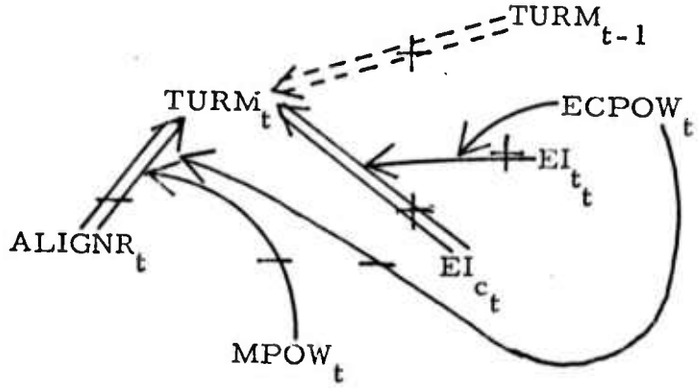
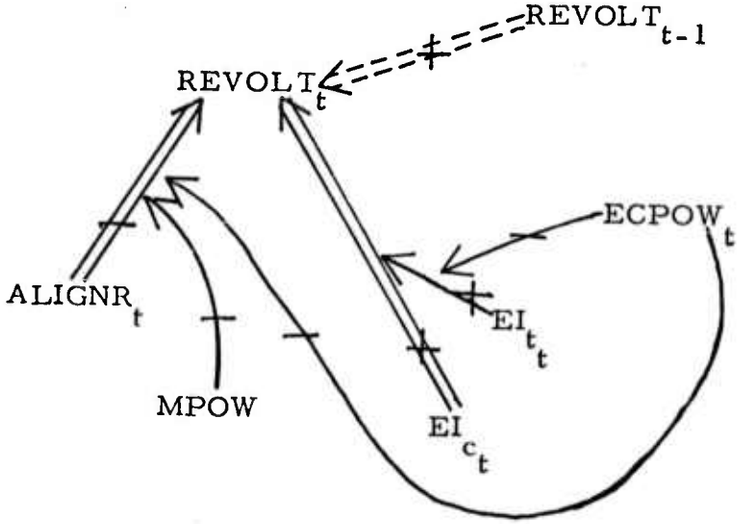
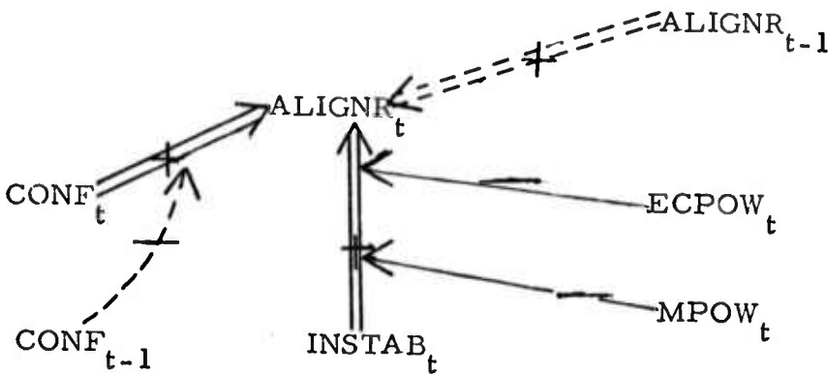
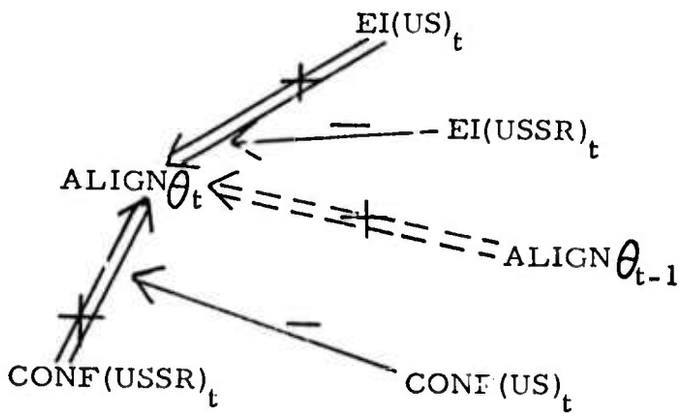
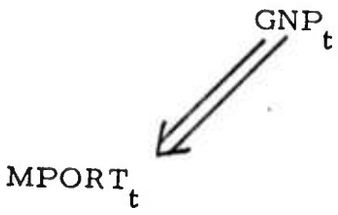
MILMAN t-1
MILMAN t
CONF t
CONF t-1
INSTAB t
POP t

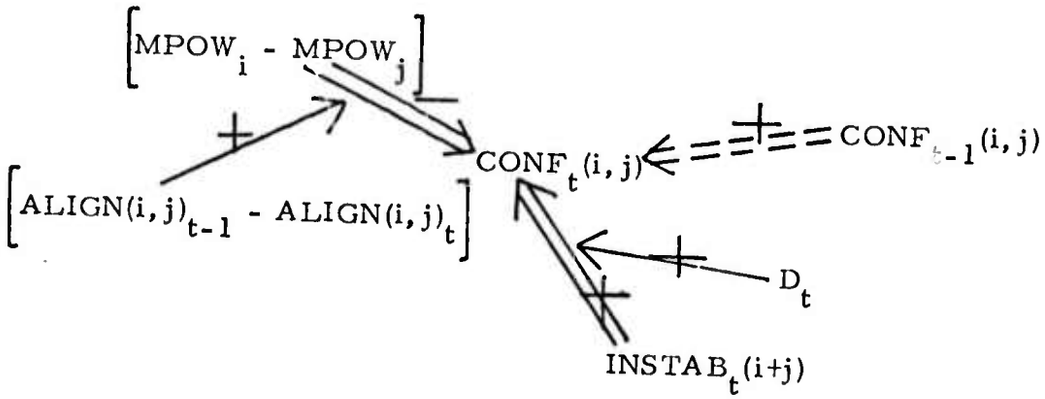

TURM t-1
TURM t
ECPOW t
EI t t
ALIGNR t
EI c t
MPOW t


REVOLT t-1
REVOLT t
ECPOW t
ALIGNR t
EI t t
MPOW
EI c t


ALIGNR$_{t-1}$
ALIGNR$_t$
CONF$_t$
ECPOW$_t$
MPOW$_t$
CONF$_{t-1}$
INSTAB$_t$


EI(US)$_t$
EI(USSR)$_t$
ALIGNθ_t
ALIGNθ_{t-1}
CONF(USSR)$_t$
CONF(US)$_t$


GNP$_t$
MPORT$_t$


[MPOW$_i$ - MPOW$_j$]
[ALIGN(i, j)$_{t-1}$ - ALIGN(i, j)$_t$]
CONF$_t$(i, j)
CONF$_{t-1}$(i, j)
D$_t$
INSTAB$_t$(i+j)